SAUNDERS

Electrolysis of Lead Sheathed Cables

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ELECTROLYSIS OF LEAD SHEATHED CABLES

BY

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THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HARRY OGDEN SAUNDERS

ENTITLED ELECTROLYSIS OF LEAD SHEATHED CABLES

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

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Electrolysis of Lead Sheathed Cable.

I.

General Description.

One of the various problems that confronts the telephone engineer of to-day, is the prevention of electrolytic corrosion of metal parts that may be buried in or have connection with the ground. Particularly is this true in large cities where the street railway companies use the ground and rails as a return circuit. The currents, returning to the grounded terminals of the generators, seek the path of least resistance, which may be the track rails, water mains, gas pipes, steel bridges, lead sheathing of cables, or any other conductor that will serve to carry the current.

The stray currents from the track may deteriorate a water main until the pressure from within causes the pipe to burst, they may corrode gas pipes, allowing the gas to escape, they may weaken the supports of steel bridges, thus rendering them unsafe, or they may eat holes in the lead sheathed cables thru which moisture penetrates, causing grounds, crosses, and shorts. It is the action of the overflow currents on lead sheathed cables that will be discussed in the following pages.

II.

Electro - Chemistry.

The outside covering of a telephone cable is composed of an alloy of lead and tin. When the cable is submerged in water or becomes moist, as will be the case when it is placed in underground conduits, the lead is subject to electrolytic corrosion by the stray currents from the track rails, which use the cable armor as a return circuit.

The term electrolysis is given to the chemical action which takes place whenever a current of electricity passes thru a conductor of the second class. Such a conductor is a chemical compound in solution, and is termed an "electrolyte," from a Greek word meaning to loosen. Electrolysis therefore may be defined as a decomposition by the action of electricity.

Electrolysis may proceed with the assistance of conductors of the first class, such as copper, zinc, iron, or lead, which conduct the current into, and out of the electrolyte. Conductors acting in this capacity are called electrodes, from a Greek word meaning to lead. The electrode which conducts the current into the electrolyte, is the anode, and the one by which the current leaves, is the cathode.

When a difference of potential exists between the electrodes and a current flows, the electrodes are not changed chemically by the current itself, but the electrolyte is split into particles

called ions, each bearing a charge of electricity. either positive or negative. Those bearing positive charges are attracted toward the negative terminal or cathode and then give up the charge. Similarly, the negatively charged ions drift thru the solvent to the positive terminal or anode and, coming in contact with it, are likewise discharged. The ions, on being liberated of their charges of electricity, become free particles of the matter of which they are composed.

The electrolyte of the earth which makes possible the electrolytic action on lead sheathed cables, is composed of moisture in the soil, together with various solutions of salts, such as sulphates and nitrates. Sodium chloride and sodium carbonate, held in solution by the moisture in the earth, are often found in the Mississippi valley soils.

When a stray current of electricity passes thru an electrolyte of the earth, the salts and moisture around the lead sheath electrodes, split up electro-chemically into non-corrosive elements and corrosive,acid,radicals. The non-corrosive elements appear at the cathode and are there deposited. The corrosive acid radicals, chiefly nascent oxygen and chlorine, are liberated on the surface of the anode, and there reunite with the lead of the sheath - provided the cable is the anode - to form various compounds of lead salts. The rate at which the chemical reaction and consequent decomposition of the anode progresses is proportional to the current flowing and the duration of its flow. Approximately seventy pounds will be taken from a lead anode per ampere year.

III.

Electrolytic Surveys.

When the corroded sheath of a cable subject to electrolytic action is examined, the lead is found to be pitted, and where the action has continued long enough, small pin holes, perforating the sheath, are visible. These corroded portions may cover only a few square inches of the sheath, or again, an entire section may be affected. In the former case, the paper insulation of the copper wires may be boiled with hot paraffine to remove the moisture and a lead sleeve substituted for the defective armor, but where a considerable length is wasted, the entire section must be cut out and a new piece of cable used in its place. This entails a heavy cost for repairs and what is often more serious, an interruption of the telephone service thru the cable.

In a vicinity where cable sheaths act as return circuits for stray currents, or even where conditions are such that there is a possibility of their carrying a current, an electrolytic survey should be made and a map of the cable system drafted, showing at each manhole or cut out point, the potential, whether electro-positive or electro-negative. Where the condition is electro-positive, the potential of the cable is higher than that of the ground or neighboring conductors and the direction of current flow is from the cable to the ground. The cable sheath is then the anode, and as such, will be corroded as previously explained. When, how-

Electrolytic Cable Corrosion

Potential Survey Before Adoption of Precautionary Measures

The + terminal of generator is connected to trolley wire.

Cross-hatching indicates area to which danger of cable corrosion is confined

Figures indicate difference of potential between cable sheaths and ground:

Signs indicate whether sheaths are electro-positive or electro-negative

Figures in parenthesis indicate time of measurment

Telephone Cable ——   Manhole ○

ever, the cable sheath is electro-negative, the potential of the ground and nearby conductors is higher than that of the cable and the currents flow on to the cable sheath. When this condition prevails, the cable sheath is the cathode, and no harm will be done to it.

A potential map, published in the "Bulletin of Electrolysis" by the American Telephone and Telegraph Company, gives a clear illustration of the data that should be taken in an electrolytic survey and the manner in which it should be plotted.

This map, here reproduced, shows the route of the cable, the location of the manholes, the telephone exchange building, and the power house in which the direct current generators have the negative terminal grounded. At each manhole the voltage from cable to ground has been measured, and the time of measurement recorded. Where the cable is found to be electro-positive, a plus mark is placed before the voltage reading, and when electro-negative, a minus sign is used.

It is well to note that in this particular survey all of the danger from electrolysis occurs in the vicinity of the power plant and the dangerous electro-positive section is indicated on the map by cross hatching. The explanation of this undesirable condition of the cable is as follows: the current from the power plant is transmitted thru the feeders and trolley wires to the car motors, thence to the car rails, and returns to the grounded terminals of the generators. But a part of the return current is shunted from the car rails to the cable sheath, according to the law of divided or

parallel circuits, making the cable a return conductor for the stray currents. When the cable line is adjacent to the power house, the stray currents leave the sheath, flowing toward the lower potential of the generator ground. At the point of departure, they subject the lead sheath to electrolytic corrosion.

It is essential in making a reliable potential survey that voltage measurements be taken for each manhole at different hours of the day. Otherwise, a point may show electro-negative at one time, whereas, at some other hour of the day when, say, the power plant is running its peak load, the conditions might be reversed and an electro-positive condition prevail. A recording voltmeter, connected to record the potential of a given section of the cable, would at times indicate a wide variation of voltages. A passing car or the simultaneous starting of several on the system would cause a sudden rise of the potential curve. If, as is sometimes the case at night, the power is shut off or very much reduced, the stray currents are small and their corrosive power negligible, yet even this condition might offer an element of danger to the life of the cable sheath.

It has been shown that a large current, flowing thru the sheath, decomposes the soluble salts in the surrounding earth, forming alkaline deposits, which will react with the lead when the currents are shut off, or considerably reduced. The magnitude of this chemical action is largely dependent on the composition of the soil of the given locality. In some sea-port towns, soil maps show a large percentage of alkaline, while in most inland cities, the percentage is relatively small. Following, is an extract from a

report entitled, "Potential Survey of the City of St. Louis."

" The subsoil upon which the city of St. Louis is built, consists principally of clay and some intermingling of sand.

From a brief chemical analysis made at divers portions of the city, the soil in the natural state was found to be as favorable to the preservation of all metallic construction as that of the average inland city.

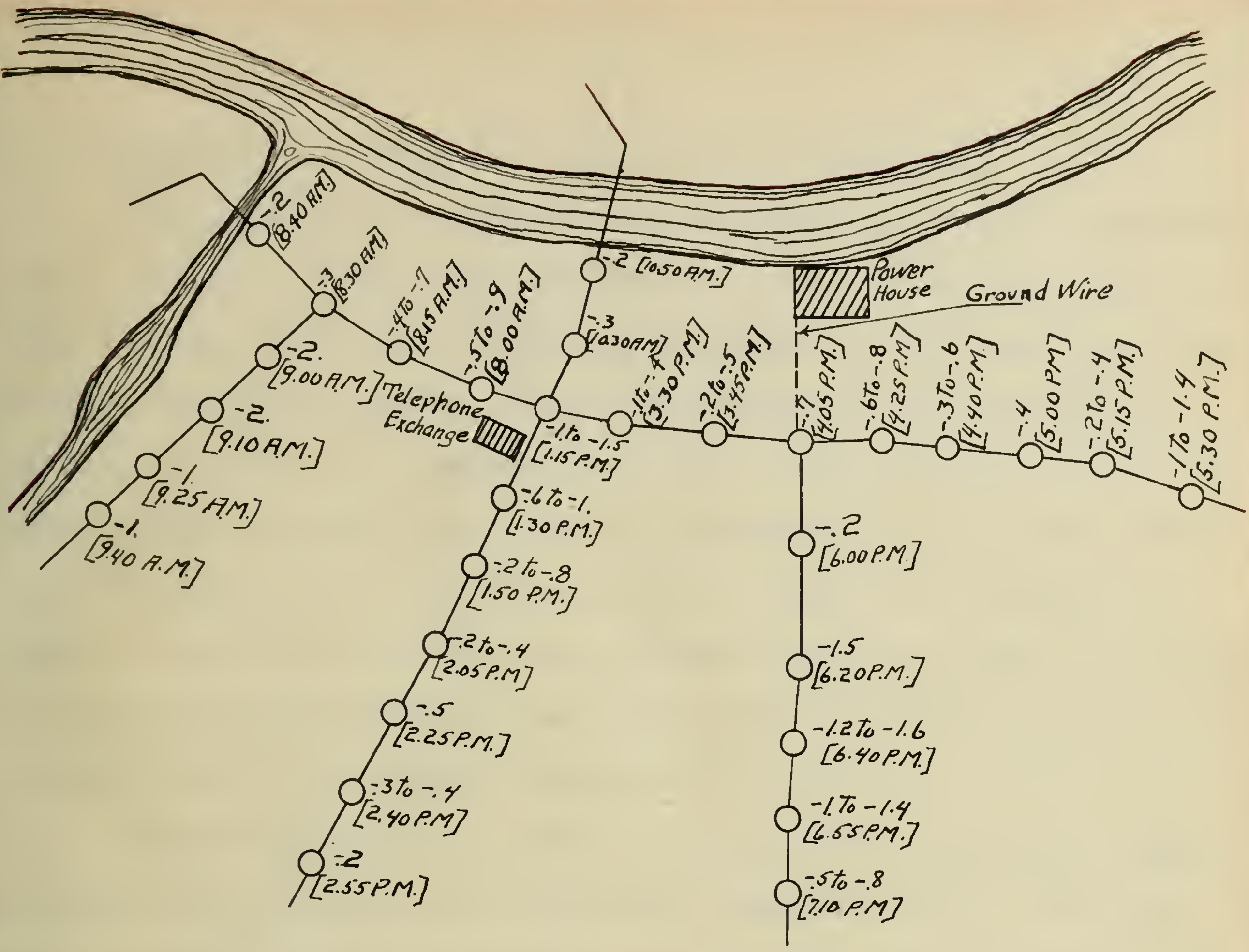
The soil taken from ditches from four to eight feet deep, has a slight alkaline reaction which will produce but little natural earth corrosion upon wrought iron construction, with practically no deteriorating effect upon either castiron or lead.

The following will show the percent of alkalinity of the soil that was taken from given locations."

Station # 1	.018 %
" # 2	.022 %
" # 3	.028 %
" # 4	.024 %
" # 5	.032 %
" # 6	.022 %
Average	.0246 %

Thus it appears on good authority that the danger from alkaline reactions with the lead sheath, is one merely of locality, and can be determined only when local conditions are investigated.

A potential survery similar to the one preceeding, but taken at a later period after the cable system had been brought to



Electrolytic Cable Corrosion

Potential Survey After Adoption of Precautionary Measures

The + terminal of the generator is connected to the trolley wire

Figures indicate difference in potential between cable sheaths and ground:

Signs indicate whether sheaths are electro-positive or electro-negative

Figures in parenthesis indicate time of measurment

Telephone Cable ———— Manhole ○

Ground Wire connected to negative terminal of generator - - - -

an electro-negative condition, will now be discussed.

The essential difference between the two, is that the danger zone, indicated on the previous map by cross-sectioning lines, is here wanting. All of the potential readings in this zone that were formerly electro-positive. have been changed to electro-negative values, by connecting the section of the cable nearest to the power house to the grounded terminals of the generator. For this connection, a copper wire of sufficient size to carry the current is used. At the same time, all the different cable sections, radiating in the various directions, have been bonded together, so that electrically, the entire cable system is intact.

These illustrations show an isolated condition which might be expected to prevail in a relatively small city, yet the laws which govern electrolytic action in one place hold good universally, and though in large industrial centers the power houses having grounded terminals are many, and the earth conductors numerous, yet in every instance the law of divided circuits governs the path thru which the stray currents flow, and the lead removed by them from a cable sheath is always proportional to the amount of current and time of flow.

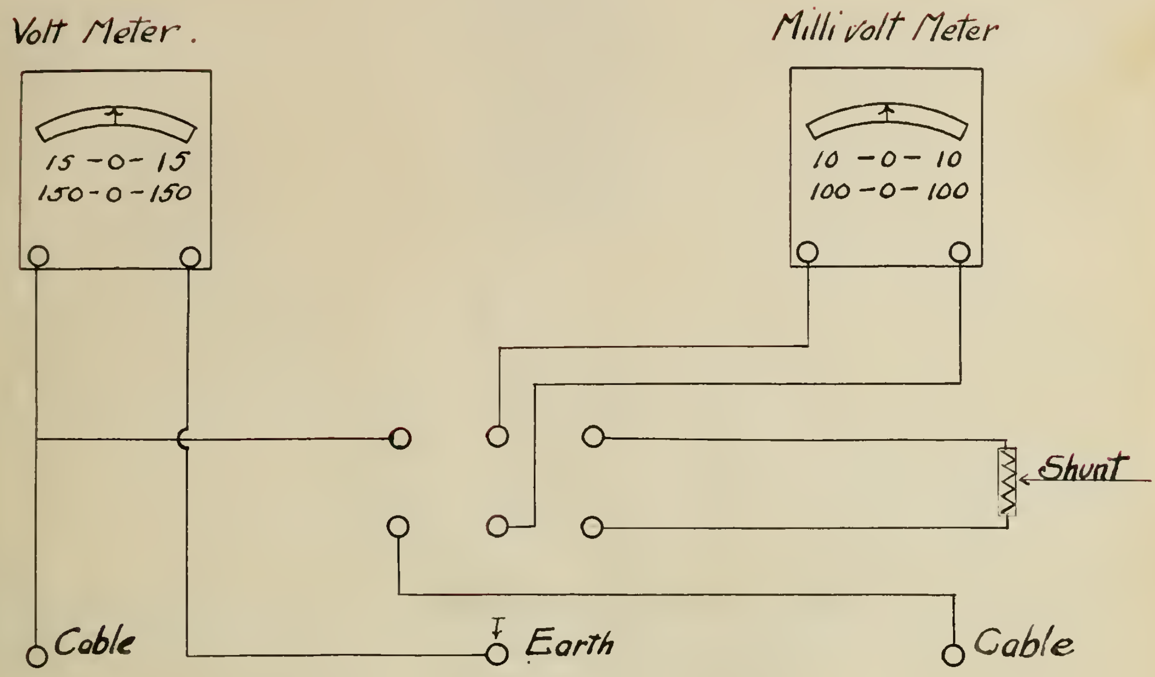
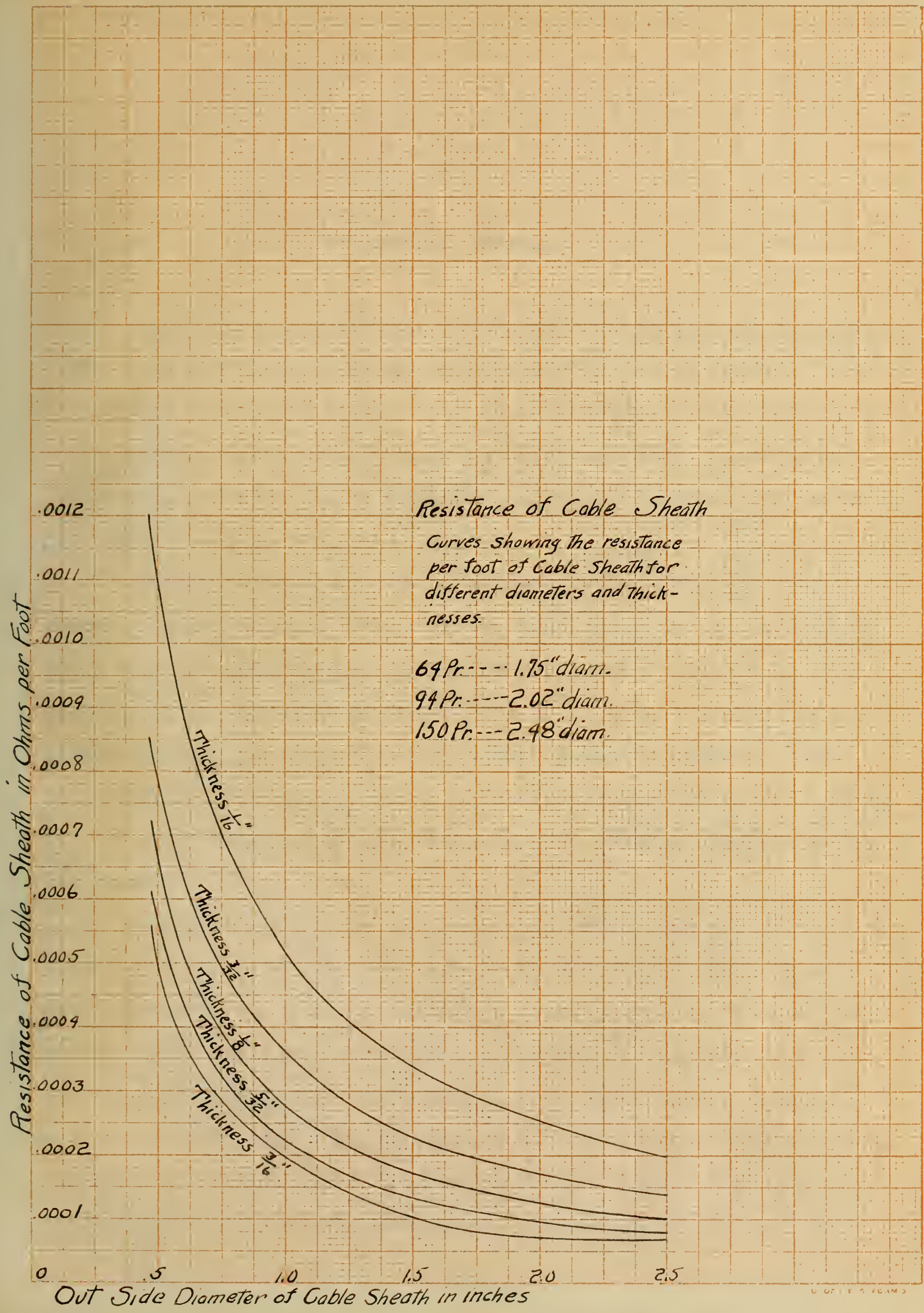


Diagram of Connection of Instruments used in making
ELECTROLYSIS TESTS.

‡ In addition to Earth reading in manhole this terminal should be connected with neighboring metallic bodies such as car tracks, gas and water mains.


Resistance of Cable Sheath
Curves showing the resistance per foot of Cable Sheath for different diameters and thicknesses.
64 Pr. - - - 1.75" diam.
94 Pr. - - - - 2.02" diam.
150 Pr. - - - 2.48" diam.
Thickness 1/16"
Thickness 3/32"
Thickness 1/8"
Thickness 5/32"
Thickness 3/16"
.0012
.0011
.0010
.0009
.0008
.0007
.0006
.0005
.0004
.0003
.0002
.0001
0
.5
1.0
1.5
2.0
2.5
Resistance of Cable Sheath in Ohms per Foot
Out Side Diameter of Cable Sheath in inches

IV.

Potential Tests.

When making a potential survey of a cable system, the simplest method of measuring the potential drop is. of course, with a voltmeter. Usually a center reading voltmeter 15-0-15 and 150-0 150, together with a center reading millivoltmeter 10-0-10 and 100-0-100,are put up in a small portable case, so that the operator may carry them from place to place.

To one terminal of the voltmeter is attached, by means of a flexible cord, a small flat strip of lead which may be lowered to the bottom of the manhole, thus giving a ground connection. The other terminal is connected electrically to a dull iron or brass point fixed at the end of a long wooden pole. By pressing this point against the cable sheath, the operator may, without descending into the manhole, obtain the potential reading between sheath and ground.

The millivoltmeter is used to determine the current flowing in the cable sheath. The method of procedure is as follows: first, measure the drop of potential across, say one foot of the cable, which for convenience of calculation, is.assumed as 5 m. v. Knowing the diameter and thickness of the cable sheath, its resistance, taken from the accompaning set of curves, is determined. Let the cable sheath be 2.5 inches outside diameter and 1/16 inch in thickness. Its resistance then is .0002 ohms per foot. (from

curve.) From Ohm's Law - $I = \frac{E}{R}$ - it is apparent that the current flowing in the sheath is:

$$\frac{.005}{.0002} = 25 \text{ amperes.}$$

Electrolytic surveys made by this simple method, are not as accurate as those made by more refined and complex methods. For extensive work, a selection of several different scale-reading voltmeters should be used to obtain potential readings, and a shunted voltmeter to get the value of current directly. In many surveys, it is important to determine the resistance of the earth between track and cable, in which case a micro-ohmmeter should be used. An idea of the earth resistance may be obtained from the following tests made between water mains and electric street car tracks at the following places:

Bronx, N. Y. ------------------.0392 ohms average.

Lockport, N. Y. ---------------.0846 " "

St. Louis, Mo. -----------------.0510.

V.

Prevention of Electrolysis.

When the local condition of an underground system of cables has been determined, it remains for the engineer to prevent the flow of harmful stray currents or mitigate their deteriorating influence. They may be entirely prevented from flowing by doing away with the ground return of the D. C. generators and substituting therefor an aerial return copper wire. This method is employed in Cincinnati, Ohio, where the street cars have two trolley poles, making contact with parallel trolley wires, to each of which one side of the generator is connected. The double trolley scheme saves a great loss of power that otherwise would be dissipated in the earth; still the grounded return system is more popular and most street railway companies are unwilling to change to the double trolley system.

To have the rails carry the largest percent possible of the return current, and thus minimize that shunted to the cable sheath, the resistance of the rails must be decreased. This is accomplished by increasing the size of rails and perfecting the bonding. Copper bonds, whether riveted or soldered, are mechanically weak and are liable to corrosion. Cast iron welds are mechanically good but electrically poor, for the steel and cast iron do not fuse readily. The more recent " thermit " welded joints seem at the present to be giving satisfaction, because of their strength and

low resistance. Electric welds are perhaps the best, having both strength and low resistance. The question of rail bonds and power circuits are evidently often beyond the control of the telephone company whose cables are effected, and so their efforts are mostly directed toward establishing safety devices in their own system.

The most perfect protection that could be afforded an underground cable system would be to insulate it from contact with ground or adjacent earth conductors thru out its entire length. This however, would in most cases call for an investment, that would not pay for itself during the life of the cable, and so is never attempted in extensive systems. A method that is helpful at times in reducing the hazard from stray currents, is to prevent them from flowing on the cable, by introducing at intervals, an insulating joint in the lead sheath, which breaks the continuity of the lead conductor. In some instances, this remedy is not successful, for the currents merely leave the cable at or near the joint, and return again at some point further on. When this method is adopted, the cable should be inspected at intervals until it is reasonably certain that the insulating joints will protect the cable at all times.

Another remedy that has been tried with doubtful success, is to run a copper wire from the cable to the ground wherever the sheath is electro-positive. These ground wires, however, may cause the stray currents to accumulate on the cable to such an extent that heating results. Heating may also occur regardless of the method of protection. Especially is this true when the size of the cable is small and it is the only one in the ducts. A copper wire

of sufficient size connected in parallel with the cable sheath, will by shunting a part of the current, decrease the I^2R loss of the sheath and thereby reduce the heating.

VI.

The Best Protection.

Where there are a number of cables in the ducts, they should all be connected together by some kind of a low resistance bond. It is customary in most constructions, to bond the cables at every manhole, thus securing a uniform conductor of low resistance. Copper wires of sufficient size, flat copper or lead strips, make the best bonds. They should never be clamped or loosely wraped around the cable sheath, but always connected by a wiped or soldered joint. When all the cables have been so connected they must, at some point or other, be connected to a low resistance conductor which is tapped directly to the power house ground plates. Some traction companies employ return copper feeders to cut down the rail resistance, and where it is feasible, the cables should be bonded to this wire at frequent intervals. Where the cable line is not adjacent to either the return feeders or the power house, lateral under-ground or aerial cables may be utilized to carry the stray currents from the cable line to the nearest return feeder or generator ground. If such laterals do not exist, a copper wire must be run, either under-ground or on pole line, to bond the cable sheath to the return feeder.

After the entire cable system has been bonded, a potential re-survey should be made to ascertain its electrolytic condition, and additional bonds and grounds should be installed where the

sheath is still electro-positive. As a final precaution it is, in extreme cases, necessary to install a quick and ready system of survey whereby the exact potential of a critical point may be measured. Take, for example, a location where the direction of flow of the current could be reversed thru the mistake of a power house attendant. The measures taken to render the cable electro-negative will be of no avail, and at many places, the cable will again become electro-positive. To guard against this change of feed, cable pairs may be brought out at the dangerous point. One conductor of the pair is connected to the ground and the other to the cable sheath, while the office end of both conductors are connected to jacks in the test desk. Then, with the office voltmeter an electrolytic survey can be made each day of the points when the cable pairs have been brought out, and proper steps taken by the management to prevent electrolytic corrosion.

VII.

Summary.

In the treatment of an electrolytic problem, it is almost impossible to follow any rigid method of procedure. Most of the large telephone companies furnish specifications covering many details pertaining to tests, bonding, etc., yet their engineers repeatedly use their best judgment in reducing the hazard from stray currents, and are always on the alert to secure better methods. At the present time, much has been done and is being done, especially in the way of securing and compiling data which shows the conditions most favorable to electrolytic corrosion. But it is the opinion of the writer that the minimum hazard will ultimately be secured in one of three ways.

First, thru the abolition of the present grounded return power systems, brought about by the introduction of a more efficient one, or by the action of the courts holding a power company liable for the damage caused by stray currents.

Second, by obtaining a substitute for the lead armor that is flexible, non-corrosive, and mechanically strong.

Third, by the active cooperation of the power and telephone companies in directing thorough investigations and experiments, and establishing suitable protective systems.